Reactivity 3.4 · Electron-pair sharing reactions

International Baccalaureate · IB Diploma · Chemistry · HL

Scope and prerequisites

This handout covers selected HL/SL topics for the course first assessed in 2025; it is not the whole syllabus.

Prerequisites: covalent bonding and polarity from Structure 2.2, alkenes and halogenoalkanes from Structure 3.2, and radical (electron-sharing) mechanisms from Reactivity 3.3.

The examples are original and fictional: they are not real measurements or real student investigations.

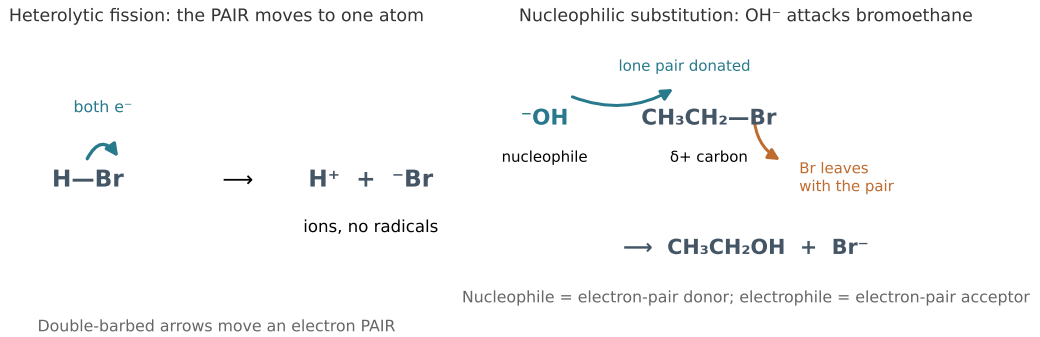
Electron-pair sharing reactions

What would explain this observation?

- Bromoethane shaken with warm sodium hydroxide solution turns into ethanol, while the same alkane skeleton with no C–Br bond ignores the hydroxide completely. What does the C–Br bond make possible?

Build the model

- A covalent bond can also break by **heterolytic fission** : BOTH electrons of the shared pair move to one atom, forming ions. A double-barbed curly arrow shows an electron PAIR moving.
- A **nucleophile** is an electron-pair donor (OH^-, CN^-, NH_3) that attacks a $\delta+$ carbon. An **electrophile** is an electron-pair acceptor (Br_2, H^+) that accepts a pair from an electron-rich region such as a C=C double bond. In the substitution of bromoethane, OH^- donates its pair to the $\delta+$ carbon while Br^- leaves with the bonding pair: $CH_3CH_2Br + OH^- \rightarrow CH_3CH_2OH + Br^-$.
- heterolytic fission: Bond breaking where one atom takes both shared electrons; nucleophile: An electron-pair donor attracted to a positive or $\delta+$ centre; electrophile: An electron-pair acceptor attracted to an electron-rich region.



In heterolytic fission the pair goes to one atom; OH^- donates a pair to the $\delta+$ carbon and Br^- leaves

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Choose evidence that can test it

- The reaction rate depends on the concentrations of BOTH bromoethane and hydroxide, supporting a mechanism in which both meet in the key step. Bromide ions appear in solution as the alcohol forms, matching the leaving-group prediction.
- Bromine water loses its orange colour with an alkene but not with the corresponding alkane – evidence that the electron-rich C=C is what attracts the electrophile.

Work from known quantities

- Known: $Mr(CH_3CH_2OH) = 46$; $Mr(CH_3CH_2Br) = 109$; $Mr(OH^-) = 17$. Atom economy measures how much reactant mass ends in the desired product: atom economy = Mr(desired product) / ΣMr(all reactants) × 100%. Substitution: $46/(109 + 17) \times 100\% = 46/126 \times 100\% = 36.5\%$. Substitution reactions have low atom economy because the leaving group carries mass away.

Example:

Chloroethane has Mr = 64.5. Find the atom economy of $CH_3CH_2Cl + OH^- \rightarrow CH_3CH_2OH + Cl^-$ using the same sequence: known quantities → model → relation → substitution → unit and interpretation. (Answer: $46/(64.5 + 17) \times 100\% = 46/81.5 \times 100\% = 56.4\%$ – a lighter leaving group raises the atom economy, though it is still far below an addition reaction's 100%.)

Check the conclusion and its limits

- The arrow-pushing model shows electron flow in the key step; real rates also depend on the solvent and temperature, which this scheme does not capture. Atom economy compares routes on paper; a full process evaluation needs yield, energy and safety data too.

Warn:

A nucleophile is a negative ion, so any negative ion is a nucleophile and any positive species is an electrophile. This claim is false: the definition is about electron-PAIR donation – neutral NH_3 is a nucleophile because it carries a lone pair, and Br^- is a leaving group, not an attacking nucleophile, in this substitution.

Key:

Electron-pair sharing reactions: heterolytic fission moves both shared electrons to one atom; double-barbed arrows track electron pairs. Nucleophiles donate pairs to $\delta+$ centres and electrophiles accept pairs from electron-rich regions; substitution and addition mechanisms follow from that flow.